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NOTES ON BIOTITE

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In the study of Minnesota rocks biotite is encountered in abundance and wide distribution. In one case it is closely related to magnetite in an iron ore prospect. These points seemed to warrant a careful test of the material. A study was planned, following somewhat the methods of Hirshi[1] and Seidel,[2] on the variation of this group of minerals with the occurrence in several kinds of rock, but adding data on the indices of refraction. This study is incomplete, but the optical data and analyses seem to warrant a few preliminary notes. Out of fourteen samples tested, thirteen had gamma and beta higher than are on record in the text books and compilations available; viz., 1.638.[3]

The recent popularity of the immersion method for determining indices of refraction makes it desirable to arrange the data for biotite in a form to use in estimating the compositions from indices. No attempt is here made at extreme accuracy of optical determination, or completeness of analysis. Such work is hardly possible on small grains of biotite constituting perhaps two per cent of a granite, especially when the biotites so commonly show a zoned structure and some variation even in a single crystal flake.[4] The index data are believed to be accurate to the second decimal for such material as the average of that analysed.

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[1] Hirshi, H., Beiträge zur Kenntnis der gesteinbildenen Biotit. Inaugural dissertation, *Zurich.* (1901)

[2] Seidel, P., *Ibid.* (1906)

[3] Rosenbusch and others give a compilation from Kohlrausch, Zimanyi, Linck and Michel-Lévy and Lacroix.

Larsen records in U. S. Geol. Survey, *Bull.* **679,** several values with beta not over 1.638.

[4] Previously noted by Hirshi, *op. cit.*

METHODS

The several biotites analyzed were separated by hand picking, Thoulet's solution, panning, rolling on paper, and the use of a magnet. Commonly the treatment with heavy solution was made two or three times. The separate was well washed and in a check test it was found that no potash was added by the treatment.

The sample was ground only to 40 mesh to avoid oxidation of the iron. Combined water was determined in a hard glass tube by Penfield's method and without prolonged blasting. The results may be a trifle low. Fluorine was not estimated in most samples. Other methods are approximately those of Hillebrand in Bulletin 700 of the U. S. Geological Survey.

The indices were compared by the Becke method with oils standardized on a goniometer, and checked by oils tested by the Geophysical Laboratory at Washington, and by oils from A. C. Hawkins, at Rochester. The optic angle was not measured, but always inspected to determine whether there was enough variation to serve as an easy method of distinction. All showed a small angle, and all good hexagonal plates had their optic planes parallel to the pinacoid (010). Pleochroism is strong in all samples. Color is stated for each.

THE SOURCES AND ANALYSES OF SAMPLES OF BIOTITE

From the fourteen biotites collected for the purpose, four have been analyzed by the writer and two others tested for iron and titanium. Tests are being conducted on the others, but none show a greater range in indices of refraction.

1. Green biotite poikilitically enclosed in feldspar in a basic segregation of the Kekequabic granite, Minnesota.
2. Brown biotite constituting about 2 per cent of the Vermilion granite, Minnesota.
3. Brown biotite constituting about 5 per cent of the granite at the quarry north of Mora, Minnesota.
4. Brown biotite (associated with hornblende) constituting about 5 per cent of the granite at Rockville, Minnesota.
5. Orange brown biotite from peridotite at the base of the Duluth gabbro, Minnesota.
6. Brown biotite from biotite schist, altered from Knife Lake slate by the Vermilion granite, Minnesota.

Partial Analyses of Minnesota Biotites

	1	2	3	4	5	6
SiO_2	38.32	37.12	35.67	36.06		
Al_2O_3	12.12	17.06	14.56	17.21		
Fe_2O_3	7.44	4.05	3.03	1.14	8.63	.64
FeO	7.72	14.80	23.23	23.75	12.96	17.60
MgO	16.55	10.21	9.24	6.16		
CaO	1.89	2.36	1.13	1.74		
Na_2O	.38	.68	.49	none		
K_2O	9.10	5.40	8.06	7.27		
H_2O+	1.20	3.10	1.02	1.28		
H_2O-	.20	.30	.23	.22		
TiO_2	1.67	2.23	3.32	2.73	4.34	1.50
ZrO_2	n.d.	n.d.	.05	1.65		
Cr_2O_3	n.d.	n.d.	.03	n.d.		
MnO	.11	.48	n.d.	.36		
F	n.d.	n.d.	.16	n.d.		
	96.70	97.79	100.22	99.57		
Sp. G.	3.021	3.107	3.125	3.125		
Indices						
Gamma	1.630±3	1.640±2	1.655±2	1.664±4	1.648±5	1.639±3
Alpha	1.580±3	1.597±5	1.605±4	1.610±5	1.584±6	1.596±4

FURTHER DATA

These analyses when compared with any compilation (such as Doelter's Handbuch der Mineralchemie, Dana's System of Mineralogy, or Osann's Beiträge zur chemischen Petrographie), show no exceptional features but the indices of refraction are nevertheless higher than might be expected. The increase of indices with increase of iron has been long understood, but these biotites are not unusually ferruginous.

Three similar records of high indices of refraction in biotites have been found in the literature. A. N. Winchell found the index of biotite in the Duluth gabbro to be above that of apatite; that is, probably above 1.638.[5] Tsuboi noted a green biotite in Japan as "unusual," because its indices were, gamma = 1.672 and alpha = 1.614.[6] Eskola found some biotites in Massachusetts with indices reaching a maximum of 1.660.[7]

With these several records showing the need of extending the limits of the index data for the group, it became of interest to see

[5] Winchell, A. N., The gabbroid rocks of Minnesota: *Am. Geol.*, **26**, 172, (1900).

[6] Tsuboi, S., *Jour. Geol. Soc. Tokyo*, **26**, 7-9, (1919).

[7] Eskola, P., Gneiss and limestone contact phenomena: *Jour. Geol.*, **30**, 269, (1922).

how far the series could be carried in the direction of increasing iron, and decreasing magnesia. Several samples in the laboratory of the University of Minnesota were from localities where the rocks and biotite had been analyzed. These were tested in oils like the others, and while the correlation of these optical data and the analyses is less accurate, the general nature of the curve seems to be indicated with fair certainty.

7. Biotite from quartz syenite, Wausau, Wis. Analysis in *Wis. Geol. and Nat. Hist. Survey, Bull.* **16**, 295, (1907). Gamma = 1.677 ± 5. Alpha = 1.612 ± 3. Fe_2O_3 = 7.87. FeO = 26.01. MgO = .76.

8. Lepidomelane from litchfieldite, Litchfield, Maine. Average of two analyses in *U. S. Geol. Survey, Bull.* **220**, 77, (1903). Gamma = 1.672 ± 5. Alpha = 1.618 ± 5. Fe_2O_3 = 21.86. FeO = 13.61. MgO = .95. The iron and titanium content of this sample was checked by work on the same sample as that tested for indices. The only notable difference was slightly more ferrous and less ferric oxide.

9. Biotite from pegmatitic granite, Rockport, Mass. Analysis in Rosenbusch, Elemente der Gesteinslehre, p. 73, (1898). Gamma = 1.677 ± 3. Alpha = 1.623 ± 5. Fe_2O_3 = 8.06. FeO = 30.35. MgO = .05.

10. Biotite from miaskite, Miask, Urals. Averages of two analyses in Iddings, Rock Minerals, p. 450, (1911). Gamma = 1.672 ± 5. Alpha = 1.614 ± 4. Fe_2O_3 = 6.24. FeO = 24.35. MgO = 5.22.

11. Biotite from quartz monzonite, Butte, Montana. Analysis in *Journal of Geology*, **7**, 743, (1899). Gamma = 1.655 ± 5. Alpha = 1.592 ± 5. Fe_2O_3 = 5.22. FeO = 13.72. MgO = 12.13.

12. Phlogopite from orendite, Leucite Hills, Wyoming. Analysis in *U. S. Geol. Survey, Bull.* **150**, 188. Gamma = 1.585 ± 10. Alpha = 1.550 ± 5. Fe_2O_3 = 2.73. FeO = .90. MgO = 22.40.

13. No biotite from Vesuvius is available here, and the optical data and analyses available in the literature may have been obtained from different flows. They are not consistent with other data.

14. Larsen in *U. S. Geological Survey, Bulletin* **679**, records a biotite with gamma = 1.574, and alpha = 1.541. These are about the lowest on record.

15. The maximum amount of iron oxide in biotite is theoretically, after Clarke, 43.84%. Doelter cites one containing 40.07% by actual test.

16. The texts usually quote for phlogopite the indices, gamma = 1.606 and alpha = 1.562 after Michel-Lévy and Lacroix. It may be suspected that this sample contained some iron oxides.

The variations in indices of refraction are plotted in figure 1, in comparison with the percentages of iron oxides. This combination of the two oxides was selected because, in the first place, the former notes on the subject suggest variation "with iron." In the second place, the variation of magnesia with the sum of the iron oxides is a fairly regular curve, while its variation with one of the iron oxides alone is much more erratic. It is noteworthy that in the compilations of biotite analyses, a high iron content, say above 25 per cent, means a low magnesia content, usually below 5 per cent. In those biotites having less than 5 per cent magnesia, however, the sum of iron oxides may vary from 20 to nearly 40 per cent.[8]

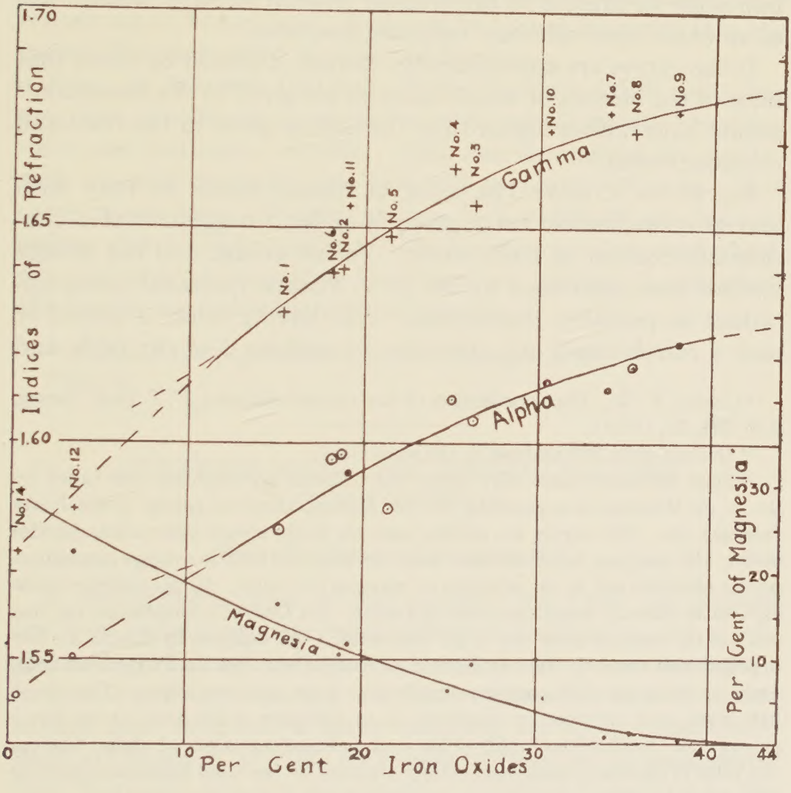

FIG. 1. The relation of iron oxides and magnesia in biotites to their indices of refraction. Crosses for the index gamma. Circles for the index alpha. Dots for the per cent magnesia. The larger crosses and circles indicate freshly determined and well correlated data. The smaller symbols are for optical tests made on biotite analyzed elsewhere.

This, of course, raises the question of the isomorphous relations of these elements and the possible oxidation of the ferrous iron in biotite. It is not the purpose of this note to discuss the structure of the biotite group, but attention should be called to one of the theories. If the molecules suggested by Clarke[9] are accepted, the theoretical maximum of ferrous oxide is around 30 per cent. The biotites from Wausau, Rockport, Litchfield, and Miask all have more than enough iron to satisfy this maximum, so that some iron must be present in the original mineral as ferric oxide,—not as an oxide isomorphously replacing magnesia.

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[8] Doelter, C., Mineralchemie, vol. 2, part 2, 680-705, (1917).

If the curves are approximately correct, it should be noted that most of the biotites of which analyses are given in the literature,[10] should have indices higher than the indices given in the texts and reference works.[11]

NOTES ON COLOR: The color of biotite seems to vary with several constituents, but a green is at least suggestive of a considerable content of ferric oxide. Yellow orange and red orange biotites were mentioned by Dr. L. V. Pirsson (personal communication) as probably titaniferoüs. Not having found a record of such a correlation I call attention to analysis 5 of the table and add the following data for three orange red samples. Biotites from contact ores of Parry Sound, Ontario, and from Thompkins Cove, Hudson River, New York, had about 3 per cent of TiO_2; that from olivine gabbro at Duluth, Minnesota, had about 6 per cent TiO_2. The most titaniferous biotite analyzed (color unknown) is probably one from shonkinite at Katzenbuckel,[12] containing 12.02 per cent. It should be added, however, that the manganiferous biotites are also red brown.

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[9] Clarke, F. W., The constitution of the natural silicates: *U. S. Geol. Survey, Bull.* **588**, 52, (1914).

[10] Doelter gives 209 analyses in the work cited.

[11] Since the above data were fairly well outlined my attention was called by Dr. A. N. Winchell to a paper by Dr. W. Kunitz, about to appear in the *Neues Jahrbuch, etc.* His curves are similar and his study covers other micas besides biotite. His analyses, however, show some peculiarities both in average amounts of certain elements and in the selection of material for study. All his analyses show high water content, suggesting some hydration. (In Doelter's compilation not one tenth of the analyses show over 5 per cent water.) All analyses by Kunitz are low in potash and alumina. He has selected no biotites with less than 9 per cent magnesia, and only six of his samples contain over 4 per cent iron oxides. The curves here given may therefore be considered as an extension of his study at the ferruginous end. Furthermore much of his work is based on values of alpha, whereas the value of gamma is much more readily obtained by the rapid immersion methods using cleavage flakes.

The ferruginous end of the series is extrapolated by Kunitz to a maximum value for alpha = 1.629. He also suggests that the oxidation of ferrous iron to ferric may raise the indices slightly above the curve shown. On the contrary, with very low magnesia I find a maximum slightly below 1.625, even when ferric oxides constitute 8 or 10 per cent of the mineral. I feel certain, therefore, that the curve bends a little down at the right. In fact the data available indicate much more definite and uniform values at this end than at the magnesian end of the series, where there may be some doubt whether fluorine and hydrogen have similar effects on the indices; and whether a magnesian biotite is really different from phlogopite.

Kunitz shows larger optic angles in places in the biotite series than I have been able to find.

NOTE ON SPECIFIC GRAVITY: From Doelter's data[13] and a few new cases, a curve was drawn for average specific gravity variations with total iron oxide content. The iron determines the gravity with an error probably less than .01 in nearly all cases. The curve ranges from 2.70 with no iron, to 3.3 with 40 per cent iron oxides, and is nearly straight. The accuracy of such work, however, is probably less than that based on indices of refraction. No further work was therefore attempted.

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[12] Rosenbusch, H., Gesteinslehre, p. 201. (Stuttgart, 1910).

[13] *Op. cit.*

FURTHER NOTES ON ATOMIC VOLUME ISOMORPHISM

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In two previous notes on this subject,[1] the writer has pointed out how certain peculiar isomorphous replacements can be explained by the atomic volume relations, but values were there given for but few of the elements. Several requests for data on others having been received, a more complete list is here presented. Radii are stated in 10^{-8} cm., and volumes, based on the assumption that the atomic domains are spheres, are derived from them by the formula $V=4/3\pi r^3$. For some purposes it will be better to consider the domains to be polyhedrons,[2] and then other formulas will apply, but these are to be discussed elsewhere.

In deriving dimensions from compounds, some of the constituents must be assumed to have a definite, fixed diameter; and since most of the best X-ray measurements have been made on oxides and halides, it is customary to apply this assumption to oxygen and the halogens. By comparing the atomic distances in oxides with those in the free forms of the corresponding metals, Bragg[3] fixed the radius of oxygen at 0.65, and there is no reason to question the general correctness of this value. By a fortunate chance, the corresponding spherical volume is near unity, so that oxygen may perhaps be considered a sort of standard of volume, as it is of atomic weight.

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[1] *Am. Min.*, **8**, 1-8, 94-95, (1923).

[2] *Am. Min.*, **9**, 45-54, (1924).

As pointed out, however, by Wyckoff,[4] Bragg's values for the halogens lead to many discrepancies between theoretical and calculated interatomic distances. They were based on comparison of the radii of the alkali and alkaline earth metals with the distances of metal from halogen in a considerable number of halides; but as these metals give evidence of being decidedly larger in the free state than in combination, such derivation of atomic radii is open to criticism. It is preferable to start with a presumably less variable metal, and silver will here be used. Assuming spherical shape, the radius of the silver atom in the free state is 1.43. The distance between silver and chlorine in cerargyrite has been accurately measured, and is 2.77, so the radius of chlorine would appear to be 1.34. As the variability in size of the silver atom may be appreciable,[5] this may well be rounded off to 1.35. This compares favorably with the mean value obtained by Richards[6] in his studies of the compressibility of the constituents of the alkali halides, namely 1.40, and is here adopted as the basis of a new series of calculations of atomic dimensions.[7]

The average values of the radii and volumes of most of the chemical elements, excluding the rare earths and some of the radioactives, concerning which there is little basis for inferences as to dimensions, are presented in table 1. As the variation from one compound to another may reach ±35% of the mean (though usually less) and as in but few cases have measurements been made with an accuracy sufficient to yield values certain to the second place, the radii are stated only to the nearest five in that place.

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[3] *Phil. Mag.*, **40**, 169-189, (1920).

[4] *Proc. Nat. Acad. Sci.*, **9**, 33-38, (1923).

[5] Thus in Ag_2O, if the radius of O is 0.65, that of Ag is 1.40, a difference of 0.03.

[6] *J. Am. Chem. Soc.*, **45**, 422-437, (1923).

[7] The newly calculated values for the halogens and for the alkali metals agree with those given by Richards well within the limits of error of the respective methods. These values also approach more closely than do those of Bragg to the radii according to Davey, *Phys. Rev.*, **22**, 211-220, (1923).

Interpolated and theoretical values are placed in parentheses. In some cases the volumes here given differ from those of the previous notes, owing to the use of the new value for Cl, as well as to the inclusion of data from recent X-ray measurements, the introduction of which has made some changes in the averages. Future work will no doubt lead to further changes, altho these seem likely to be in most cases but slight.

TABLE 1. AVERAGE DIMENSIONS OF ATOMS OF THE ELEMENTS

ELEMENT	RAD.	VOL.	ELEMENT	RAD.	VOL.	ELEMENT	RAD.	VOL.
1.H	0.95	3.6	25.Mn	1.50	14.1	49.In	(1.5)	14.1
2.He	(1.0)	4.2	26.Fe	1.30	9.2	50.Sn	1.40	11.5
3.Li	1.25	8.2	27.Co	1.30	9.2	51.Sb	1.50	14.1
4.Be	1.15	6.4	28.Ni	1.35	10.3	52.Te	1.40	11.5
5.B	(1.0)	4.2	29.Cu	1.10	5.6	53.I	1.70	20.6
6.C	0.70	1.4	30.Zn	1.35	10.3	54.Xe	(2.0)	33.5
7.N	0.65	1.2	31.Ga	(1.3)	9.2	55.Cs	2.20	44.6
8.O	0.65	1.2	32.Ge	1.20	7.2	56.Ba	2.10	38.8
9.F	0.85	2.6	33.As	1.30	9.2	......	....	
10.Ne	(1.2)	7.2	34.Se	1.20	7.2	72.Hf	(1.7)	20.6
11.Na	1.50	14.1	35.Br	1.50	14.1	73.Ta	1.40	11.5
12.Mg	1.45	12.8	36.Kr	(1.7)	20.6	74.W	1.35	10.3
13.Al	1.40	11.5	37.Rb	1.95	31.1	75.—	(1.4)	11.5
14.Si	1.15	6.4	38.Sr	1.90	28.7	76.Os	1.35	10.3
15.P	(1.1)	5.6	39.Yt	(1.8)	24.4	77.Ir	1.35	10.3
16.S	1.05	4.9	40.Zr	1.60	17.2	78.Pt	1.40	11.5
17.Cl	1.35	10.3	41.Cb	(1.3)	9.2	79.Au	1.45	12.8
18.A	(1.6)	17.2	42.Mo	1.35	10.3	80.Hg	1.60	17.2
19.K	1.80	24.4	43.—	(1.4)	11.5	81.Tl	1.95	31.1
20.Ca	1.75	22.4	44.Ru	1.35	10.3	82.Pb	1.80	24.4
21.Sc	(1.7)	20.6	45.Rh	1.35	10.3	83.Bi	1.55	15.6
22.Ti	1.45	12.8	46.Pd	1.40	11.5	......	....	
23.V	1.30	9.2	47.Ag	1.40	11.5	90.Th	1.80	24.4
24.Cr	1.25	8.2	48.Cd	1.65	18.8	91.Bv	(1.6)	17.2
						92.U	(1.4)	11.5

The relation between some of the peculiar cases of isomorphism and the elementary dimensions can best be brought out by restating these data in another form, and this is done in tables 2 and 3 In the first of these the elements are arranged in a periodic table in the order of their atomic number, the form used having the advantage of not requiring the usual but meaningless grouping of Cu, Ag and Au with the alkalies, Mn with the halogens, etc.

The letters used at the heads of columns refer to the more important system of crystallization of the elements; here: C=

TABLE 2. ELEMENTS ARRANGED IN AN ATOMIC-NUMBER PERIODIC TABLE

Crystn.	C	HC	CH	CH	C	C	C	CH	CH	C	C	H	T	CT	CH	OH	O	C
	H																	He
	Li	Be	B	C											N	O	F	Ne
	Na	Mg	Al	Si											P	S	Cl	A
	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
	Rb	Sr	Yt	Zr	Cb	Mo	43	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
	Cs	Ba	(RE)															
				Hf	Ta	W	75	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	85	Rd
	87	Ra	Ac	Th	Bv	U												

TABLE 3.. ELEMENTS ARRANGED IN AN ATOMIC-DIMENSION PERIODIC TABLE

rad.	vol.																		
0.65	1.2															N	O		
0.70	1.4				C														
0.75	1.8																		
0.80	2.1																		
0.85	2.6																	F	
0.90	3.1																		
0.95	3.6	H																	
1.00	4.2			(B)															(He)
1.05	4.9																S		
1.10	5.6											Cu				(P)			
1.15	6.4		Be		Si														
1.20	7.2														Ge		Se		(Ne)
1.25	8.2	Li					Cr												
1.30	9.2					V	Mo		Fe	Co				(Ga)		As			
1.35	10.3					(Cb)	W		Ru	Rh	Ni		Zn					Cl	
1.40	11.5			Al		Ta	(U)	(43)	Os	Ir	Pd	Ag			Sn		Te		
1.45	12.8		Mg		Ti			(75)			Pt	Au							
1.50	14.1	Na						Mn						In		Sb		Br	
1.55	15.6															Bi			
1.60	17.2				Zr	(Bv)							Hg						(A)
1 65	18.8												Cd						
1.70	20.6			(Sc)	(Hf)													I	(Kr)
1.75	22.4		Ca																
1.80	24.4	K		(Yt)	Th										Pb				
1.85	26.5																		
1.90	28.7		Sr	(RE)															
1.95	31.1	Rb												Tl					
2.00	33.5																		(Xe)
2.05	36.1																		
2.10	38.8		Ba																
2.15	41.6																		
2.20	44.6	Cs																	

Noteworthy radius differences between and up columns.

Cs—Rb =0.25	Rb—K =0.15	K—Na =0.35	Na—Li =0.25	Li—H =0.30
Ba—Sr =0.20	Sr—Ca =0.15	Ca—Mg =0.30	Mg—Be =0.30	....
(RE—Yt =0.10)	(Yt—Sc =0.10)	Sc—Al =0.30	Al—B =0.40	....
....	Zr—Ti =0.15	Ti—Si =0.30	Si—C =0.45	....
....	Sb—As =0.20	As—P =0.20	P—N =0.45	....
....	Te—Se =0.20	Se—Sl =0.15	S—O =0.40	....
....	I—Br =0.20	Br—C =0.15	Cl—F =0.50	....
....	Xe—Kr =0.30	Kr—A =0.10	A—Ne =0.40	(Ne—He =0.20)
(decreasing)	(increasing)	(decreasing)	(increasing)	(decreasing)

Cubic, T = Tetragonal, H = Hexagonal, including Trigonal, and O = Orthorhombic.

In most of the columns of table 3 the order of increasing size of the elements is the same as that of increasing atomic number (table 2) on which the usual periodic table is based. Exceptions appear to occur in several places, but in none of these have the measurements been made with sufficient certainty to show the reality of the reversal. The atomic weight periodic table contains, however, at least three reversals (the high weights of A, Co and Te), so that it is not impossible that the atomic dimension table also contains some.

The dimensional source of the isomorphism of Na and Ca (and of K and Ba) as urged in the writer's previous articles, is less evident when the new values for these elements are used. However, the values for the alkaline earth metals are very imperfectly known, and moreover, the ability to vary 10% in radius which is evidently possessed by many of the elements (some indeed appearing to vary as much as 35%) would enable even the listed dimensions of Na and Ca to overlap. Other instances of cross-column isomorphism with valence dissimilarity show closer dimension similarity: for example, Mg/Al, Ca/Yt, Ti/Cb, V/Mo, Zn/Ga, Ge/As, Sn/Sb, P/S, and Sb/Te.

SUMMARY—In this paper new atomic radius and volume data are calculated and tabulated in a form which it is hoped may prove useful to mineralogists working on isomorphism as a phenomenon connected with atomic dimensions. For deriving radii from compounds, the radius of oxygen is taken to be 0.65, following Bragg; but the value for chlorine is based on silver and silver chloride, and comes out as 1.35. Average values are given for the radii, and for the volumes on the spherical basis, of most of the elements, and the bearing of the data on certain peculiar cases of isomorphism is discussed.

A SIMPLE ROTATION APPARATUS

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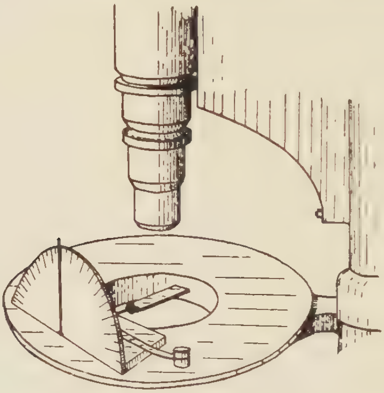
Numerous types of rotation apparatus for the measurement of axial angles and the determination of the angles between faces on small crystals have been devised for microscopic work. All such devices, however, add in varying amounts to the cost of microscopic equipment. Therefore, it is assumed that users of microscopes might be interested in a very simple rotation apparatus that can be quickly constructed for a negligible cost and will give fairly accurate results.

This device, shown in the accompanying sketch, may be easily clamped to the stage of any microscope and as easily removed. It consists of a base of wood 2 cm. wide, 4.5 cm. long and 4 mm.

thick to one side of which is tacked a graduated semicircle with a radius of 2.25 cm. The base has a small groove cut on the lower side just large enough to hold a small stiff wire which acts as a rotation arm. The wire is held in the groove by means of fine thread passed through four small holes drilled in the base, two on each side of the groove. One end of the arm is bent to fit the semicircle and acts as a pointer for reading angles. A thin strip of cover glass, not over 1.5 mm. in width, is fused to the other end of the wire and serves to hold the object under examination. Glasses may be quickly fused to the wire with a carefully directed blowpipe flame. One method is to set the apparatus with the arm in place and pointer vertical on a small mineralogist's anvil and place one end of a small glass strip on the tip of the arm. Then, with the application of a fine, well directed flame one end of the strip may be melted and will stick to the wire when cool. It is a matter of importance that the width of the glass strips be limited to about 1.5 mm. for it is inconvenient to work with objectives having short focal lengths when the glasses are wider. Such pieces may be cut from ordinary cover glasses with a diamond pointer commonly used for marking microscopic slides or may be broken at random, those of the proper size being saved.



Sketch showing the rotation apparatus in position for use

The fragment or small crystal to be studied is placed on the glass and held in place with a small drop of oil or Canada balsam dissolved in xylol. The tension in the liquid is sufficient to hold the fragment on the glass even when it is rotated to a vertical position. The rotation is accomplished by moving the pointer.

In test measurements of 2 E for muscovite the average of five readings agreed within a degree with the value obtained with a universal apparatus. Muscovite, however, provides unusually good material for such measurements. The apparatus, it seems, may nevertheless be relied upon to give angles that are within 2 or 3 degrees of the correct values in all cases where a good image may be secured in the microscope. Axial angles with 2 E as high as 120° have been measured successfully. The results secured, however, depend largely upon the nature of the material. The measurements of axial angles for fragments mounted in liquids should be corrected for the effect of the mounting medium. This correction is usually small and may be overlooked in ordinary work or may be rendered unnecessary if one end of a fragment under investigation is fastened to the glass with a small amount of viscous Canada balsam and the observation is made on the opposite end in air alone. No correction need be made if an oil is used with an index of refraction equal to β.

PROCEEDINGS OF SOCIETIES

PHILADELPHIA MINERALOGICAL SOCIETY

Academy of Natural Sciences, May 8, 1924

A stated meeting of the Philadelphia Mineralogical Society was held on the above date with the president, Mr. Vaux, in the chair. Twenty-two members and five visitors were present. Upon favorable recommendation of the council, the following were elected active members: Messrs. J. Carroll Moerk, Thomas J. Lewis, and Harold Rosen. Mr. Boyle proposed the following for active membership: Messrs. J. H. Boyle and Herbert Haas.

Mr. Morrell G. Biernbaum addressed the society on *Gemstones, Real and Otherwise.* Data were given regarding the dispersion and refractivity of the principal gemstones. Commercial stones were classified as real, imitations (chiefly glass), "doctored" (doublets and triplets), substitutes, synthetic, and reconstructed. The manufacture and composition of the latter were described, followed by a list of trade names of many gems.

Mr. Samuel G. Gordon presented a paper on *The Composition of Thomsonite.* The formula ratios of over seventy analyses were calculated and plotted. The results were interpreted as indicating that thomsonite represents mixed crystals of calciothomsonite: $CaO \cdot Al_2O_3 \cdot 2SiO_2 \cdot 3H_2O$, and a soda compound: $Na_2O \cdot Al_2O_3 \cdot 3SiO_2 \cdot H_2O$, which is natrolite with but one molecule of water. The latter can enter into the mixed crystals only to the extent of about 50%. Any intermediate compound would have the formula: $n(CaO+Na_2O) \cdot n(Al_2O_3) \cdot 2n+1 (SiO_2) \cdot 3n-2(H_2O)$, where n is the sum of the formula ratios of CaO and Na_2O the latter being considered as 1.

Trips to Moore Station were described by Messrs. Lewis and Biernbaum, on which much stilbite, calcite, and natrolite were obtained. Mr. Cienkowski reported a visit to Mullica Hill, and Mr. Millson, one to Mineral Hill, where the usual minerals were obtained.

Samuel G. Gordon, *Secretary.*

Academy of Natural Sciences, June 12, 1924

A stated meeting of the Philadelphia Mineralogical Society was held on the above date with the president, Mr. Vaux, in the chair. Twenty-eight members and thirteen visitors were present.

Mr. Frederick Oldach addressed the society on the "*Pyroxenes and Amphiboles.*" The crystallographic relations of the pyroxenes and amphiboles were described, followed by a discussion of their classification, and a review of the older and more modern theories of their composition. Many specimens were exhibited. A vote of thanks was extended to the speaker for his instructive communication.

Messrs. Trudell, Biernbaum, and Cienkowski described various phases of the Society's excursion to Falls on French Creek on May 30-June 1, participated in also by Messrs. Vaux, Gordon, McClure, White, Rosen, Faust, Hoadley, Boyle, Arndt, Moerk, Wills, and Frankenfield. Specimens of apophyllite, pyrite, erythrite pyrrhotite, and chalcopyrite were exhibited.

Mr. Biernbaum described a trip to Branchville, Conn. with Mr. Hoadley. Smoky quartz, beryl, albite, microcline, and spodumene were collected. Four trips to Moore Station, New Jersey were reported by Messrs. Boyle, Wills, Benge, Trudell, Gordon, Biernbaum, Thatcher, and Frankenfield. Many fine specimens of stilbite, natrolite, and calcite were found. Mr. Benge exhibited vivianite from Mullica Hill.

Mr. Gordon reported an excursion to the Line Chrome Pit in Maryland on May 2, with Drs. Schaller, Shannon, Foshag, and Ross. Williamsite, kammererite, magnesite, and chromite were found. On May 10, he visited Quincy, Mass., in company with Drs. Palache, Larsen, and Gilson, finding some riebeckite.

On behalf of the special class in mineralogy at the Northeast High School, Mr. Rosen presented Mr. Biernbaum with specimens of realgar and tennantite from the Binnenthal, as an expression of their appreciation for his instruction.

Samuel G. Gordon, *Secretary.*

BOOK REVIEWS

MIKROSKOPISCHE PHYSIOGRAPHIE DER MINERALIEN UND GESTEINE. Rosenbusch-Wülfing, 5th edition, fully revised. Vol. I, First Half, octavo, pages 253-532 with 349 text figures and 2 plates. E. Schweizerbart'sche Verlagsbuchhandlung, *Stuttgart*, 1921.

This delivery constitutes the second section of volume one of this standard reference work. (For review of the first section see *Am. Min.*, 1922, 7, 211.)

The subjects discussed include geometrical optics, the hand lense and its use, the microscope and its use, including the measurement of lengths, surfaces, and angles, the determination of extinction angles, and the application of the universal methods of Fedorow. The text is profusely illustrated. E. H. Kraus

PETROLOGY FOR STUDENTS. AN INTRODUCTION TO THE STUDY OF ROCKS UNDER THE MICROSCOPE. ALFRED HARKER. 6th edition, revised. 302 pages with 100 text figures. Cambridge University Press, *London*; The MacMillan Co., *New York*, 1923.

The popularity of this book as a text for students in petrology is clearly shown by the rapid succession in which new editions follow one another. The subject matter and presentation in the sixth edition conform very closely to that of the fifth edition which appeared in 1919. A few new figures have been added and some old ones have been withdrawn. Of the 300 pages, slightly more than two-thirds of the book is devoted to a discussion of igneous rocks, about 60 pages to sedimentary rocks and 40 pages to the effects produced by thermal and dynamic metamorphism.

Judged from an American standpoint, in the opinion of the reviewer, this edition, like the previous one, suffers from three minor weaknesses. (1) Not a single chemical analysis is recorded in the entire book. (2) As a text for.the "English-speaking students" greater emphasis should have been given to the description and occurrence of rock types in America. (3) In recent years unusual progress has been made along the line of quantitative petrology. Not only has the chemical system (commonly referred to as the C. I. P. W. system) been firmly established in America, but more recently a rational mineralogical quantitative system (Johannsen) has been proposed as well. It would seem that a chapter or two devoted to this phase of petrology would have been quite appropriate and exceedingly helpful to both English and American students. W. F. H.

NEW MINERALS: NEW SPECIES

CLASS: SULFO-SALTS. DIVISION: $RS:R_2S:Sb_2S_3=5:9:7$.

Berthonite

H. BUTTGENBACH: Sur un nouveau Mineral Provenant de Tunisia. [On a new mineral found in Tunisia.] *Ann. soc. geol. Belg.* **46**, 212, (1923).

NAME: In honor of M. *Berthon*, mining engineer.

CHEMICAL PROPERTIES: *Formula*, $5PbS.9Cu_2S.7Sb_2S_3$. Theory, Pb 20.79, Cu 22.96, Sb 33.75. Analysis gave Pb 21.83, Cu 23.68, Sb 32.45. Gives the usual blowpipe reactions for lead, copper and antimony. Easily fusible.

PHYSICAL PROPERTIES: Fine granular without cleavage; metallic luster; color lead gray; streak black; density 5.49; hardness 4 —5.

OCCURRENCE: Associated with galena in small, later veins in the iron mines of Slata, Tunisia.

DISCUSSION: This mineral has been examined minerographically by Mr. E. B. Samson. The material was found to be essentially homogeneous. A few minute veins, of what is apparently limonite, penetrate the mass and become abundant near the border of the veins. The mineral appears to be isotropic. No structure was developed by etching. With conc. HNO_3 the mineral is strongly attacked with effervescence. Negative with HNO_3, HCl, KOH, KCN, $HgCl_2$, $FeCl_3$. With acid $KMnO_4$ (1 cc. conc. $KMnO_4$: 1 cc. H_2O with 1 drop H_2SO_4) quick tarnish, at first brown, then blue when heavier. After about 2 min. becomes persistent and will not rub off. HCl dissolves tarnish and leaves bright unattacked surface. Alk. $KMnO_4$ as with acid $KMnO_4$. Bournonite, in contrast with these reactions, is not attacked brown by HNO_3; is attacked brown by alk. $KMnO_4$, developing structure. Bournonite is distinctly anisotropic in polished section.

Berthonite is apparently distinct from bournonite, the only other lead copper sulf-antimonide. It is evidently a new species although its exact formula is in doubt.

W. F. F.

CLASS PHOSPHATES, ETC. DIVISION; R′ : R″ : Sb=1:2:2.

Weslienite

Gustav Flink: Weslienite, ett nytt mineral från Långbans Gruvor. (Weslienite, a new mineral from the Longban Mine.) *Geol. Fören. Förh.*, **45**, 567, (1923).

Name: From J. G. H. *Weslien*, manager of the Longban Mine.

Chemical properties: An antimonate of calcium, sodium and iron, $Na_2FeCa_3Sb_4O_{15}$. Analysis by Dr. G. Karl Almstrom: Sb_2O_5 67.37, As_2O_5 tr., FeO 6.56, MnO tr., CaO 17.91, MgO 1.24, K_2O 0.62, Na_2O 5.40, ign. 1.03, sum 100.13. Theory Sb_2O_5 68.0, CaO 17.8, FeO 7.6, Na_2O 6.6.

Crystallographic properties: Isometric, octahedral in habit. Forms: *o* (111), *a* (100), *m* (110), *n* (331), *e* (311). Crystals up to 2 mm. in size.

Physical and optical properties: Color, honey-yellow to resinous brown. Luster, vitreous to adamantine. Fracture splintery. H 6.5. Sp.Gr. 4.967. Anomalously birefracting, optically positive with large axial angle. Shows anomalous birefringence color of a violet blue and undulatory extinction. Index of refraction for sodium light, 2.21.

Occurrence: Found at the Hindenburg workings of the Longban Mine. Forms isolated individuals or druses in massive hematite associated with manganophyllite, richterite and a pale berzelite or adelite—like mineral. A later filling is partly hedyphane and partly calcite.

Discussion: Weslienite is a mineral similar to atopite, romeite or schneebergite but apparently differs from all of these. The relationships of these minerals, however, are not well understood. They may be compared as follows; Romeite,$5RO.3Sb_2O_5$. Atopite, $2RO.Sb_2O_5$. Weslienite, $5RO.2Sb_2O_5$. Schneebergite, $2RO.Sb_2O_4$. It will be seen that atopite lies half way between romeite and weslienite while schneebergite has antimony in two states of oxidation. Weslienite should ther fore be classed as a distinct species until some definite relationship can be shown to exist between it and romeite and atopite.

W. F. Foshag.

CLASSIFIED LIST OF MINERALS DESCRIBED OR DISCREDITED DURING 1922

"Keeleyite"	$3PbS.4Sb_2S_3$?	A var. of zinkenite?	8, 167
Germanite	$Cu_{11}AsGeS_{12}$?	A new sulfo-salt	8, 115
Becquerelite	UO_3+xH_2O	A new hydroxide	7, 179
"Iron-rutile"	$TiO_2+Fe_2O_3$	=admixed ilmenite	7, 185
Sodium bicarbonate	$NaH(CO_3)$	Reported in nature	7, 87
"Hoelite"	$C_{14}H_8O_2$	Anthraquinone	9, 118
Vauxite	$Fe_4Al_4P_6O_{25}(H_2O)_{27}$?	A new hydro-phosphate	7, 108
Paravauxite	$FeAl_2P_2O_9(H_2O)_{11}$?	A new hydro-phosphate	7, 108
(Division assignment of	the two preceding)		8, 151
Sincosite	$Ca(VO)_2(PO_4)_2+xH_2O$	A new hydro-phosphate	7, 163
Dewindtite	$Pb(UO_2)_2(PO_4)_2+xH_2O$	A new hydro-phosphate	7, 162
"Stasite"	same as preceding	A var. of dewindtite?	7, 196
Ceruleofibrite	basic copper chlor-sulfate	=Connellite	7, 80 9, 55
"Acrochordite"	$Mn_5(OH)_4(AsO_4)_2(H_2O)_4$	Data incomplete	8, 167
"Rauvite"	a Ca-U vanadate	Not yet characterized	8, 187
(Unnamed)	$Fe_7(UO_2)_3Ce_2Cb_{12}O_{43}$	A new columbate	7, 197
Ishikawaite	same as preceding	Now established and named	8, 230
Gillespite	$FeBaSi_4O_{10}$	A new acid silicate	7, 147
"Rivaite," "Reaumurite"	Complex pyroxenes	=impure wollastonite	7, 64
Bustamite	$CaMn(SiO_3)_2$	established as subspecies	7, 95
Tuxtlite	complex pyroxene	established as subspecies	9, 18
"Mayaite"	a series	=tuxtlite-albite series	9, 18
"Gavite," "picrosmine"	hydrous talcs	varietal status shown	7, 167
"Mansjoeite"	$MgCa(SiO_3)_2+1/8MgF_2$	=fluoriferous diopside	8, 168
Thortveitite	$Sc_2Si_2O_7$	Redefined	7, 195
"Mineral A"	$MgCa(SiO_4)$	=monticellite	7,47,6
Kochite	$Al_4(SiO_4)_3(H_2O)_5$	A new hydro-silicate	9, 18
Soddite	$(UO_2)_5Si_2O_9(H_2O)_6$?	A new basic hydro-silicate	7, 179
"Soda-glauconite"	natriferous glauconite		9, 118
(unnamed)	Mn hydro-silicate	Optically distinct	7, 152

The classified list for 1921 appeared on page 34 of this volume. E.T.W.

ABSTRACTS

MORENOSITE FROM JOACHIMSTHAL. František Ulrich. *Časopis Musea Českêho*, 95, 123-4 (1921); thru *Mineral. Abstr.*, **2**, 141.

Morenosite, with only a trace of admixed $FeSO_4.7H_2O$, occurs as an efflorescence on mixed sulfide ores. The optical characters of this new morenosite agree with those recorded for other localities. E. F. H.

NOTE ON THE MORPHOLOGY OF PYRITES FROM ŠŤÁVNICE. František Ulrich. *Sborník Klubu Přírodovědeckého v Praze*, **1922**, for 1914–20, 5 pp.; thru *Mineral. Abstr.*, **2**, 141.

Pyrite crystals from the propylitic veins of Šťávnice in Slovakia show three forms new for the locality. E. F. H.

NEW FORMS ON AMPHIBOLE FROM JAPAN. M. J. Marek. *Rozpravy České Akad.*, cl. 2, 30, no. 34, 4 pp. (**1921**); thru *Mineral. Abstr.*, **2**, 143.

Tridymite and small dark brown to black amphibole crystals occur in cavities in an andesite from Shimasaki-mura, Hotaku-gori, Rigo prov. The amphibole crystals were found to have 6 new forms: (650), (560), (120), (270), (102), (261). E. F. H.

CRYSTALS OF WULFENITE FROM KAS-KAI-GUIR, KARKALINSK DISTRICT, SEMIPALATINSK PROV. E. Flint. *Coll. Mineral. Cabinet Moscow Univ.*, **1919**, for 1917, 51-60; thru *Mineral. Abstr.*, **2**, 138.

There are three types of crystals: cube-like and prismatic, pyramidal, and tabular. $a:c = 1:1.5746$. Etching experiments had no result. E. F. H.

CONTRIBUTION TO THE MORPHOLOGY OF STIBNITE FROM ALLCHAR AND BAIA SPRIE. Bohuslav Ježek. *Rozpravy České Akad.*, cl. 2, 30, no. 28, 6 pp. (1921). NEW MEASUREMENTS ON STIBNITE FROM PŘÍBRAM. *ibid.*, no. 24, 4 pp.; thru *Mineral. Abstr.*, **2**, 140-1.

Six new forms, for the mineral, were found on stibnite from Allchar: (679), (359), (2.5.14), (147), (195) and (319). One new form for the species was noted on crystals from Baia Sprie (Felsöbánya): (234). Three new forms for stibnite were measured on material from Bohutín in the Příbram district: (293), (2.1.12), and (4.3.16). E. F. H.

BROOKITE FROM BOBRŮVKA. František Ulrich. *Rozpravy České Akad.*, cl. 2, 31, no. 8, 4 pp. (**1922**); thru *Mineral. Abstr.*, **2**, 141.

Crystals of muscovite, apatite and brookite occur in the cavities of a pegmatite consisting of albite, smoky quartz and black tourmaline. The brookite has one form: ω (944). Spectroscopic analysis showed the presence of Ti, Fe, Sn, Pb, Si, Ge and perhaps also Nb, Ta, and W. E. F. H.